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ABSTRACT

Electroencephalographic studies were done on 25 dyslexic and 25 normal reading children (all between the ages of 8 and 13 years). Results indicated that, of dyslexic Ss showing evidence of unresolved dominance in the EEG recordings, 35 percent of cases were possibly genetically determined with a further 40 percent possibly neurologically impaired. Inter-group findings revealed differences in the amount of alpha activity in the two hemispheres with dyslexic Ss showing more activity on the dominant side or no difference at all, whereas controls showed more activity on the non-dominant side. Findings suggested the presence of lateral dominance and cortical organization in the control group on normal readers and no comparable resolution of dominance in both the genetically and neurologically determined cases of dyslexia. (DB)

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A NEURO-PSYCHOLOGICAL INVESTIGATION INTO DYSLEXIA

MARGARET NEWTON

The Phenomenon

The term 'dyslexia' denotes a cognitive disorder manifested by difficulty in coding language forms, especially in reading, despite adequate intelligence, conventional instruction and socio-cultural opportunities.

Among the observable behavioural symptoms are persistent reversal and dis-ordering of letters, syllables and word-order when speaking, reading or writing; mirror imaging of letters; inability to perceive, code and subsequently retain a consistent meaningful symbolic image; the consequent inability to retrieve and express a relevant meaningful output of linguistic material; severe spelling disorder; non-resolution of hand and eye dominance; late development of spoken language in early childhood; sometimes motor clumsiness; sometimes hyper-activity; sometimes superior ability in spatial skills, in direct contrast to the disability in linguistic skills.

It is estimated that at least ten per cent of the school population in Britain have this linguistic coding disability; if the condition is of poly-genetic origin and occurs on a continuum ranging from minimal to gross disability it is likely that a much larger percentage of people will be affected to some degree.

Historical Survey

Dyslexia was first recognised by James Hinshelwood, a Glasgow ophthalmologist who published in *The Lancet* in 1895 a paper on *Visual Memory and Word Blindness*. From 1900–1917 he wrote extensively on the topic and described the condition as being due to difficulties in interpreting and understanding written symbolic texts and not due to specific eye defects. He postulated that the condition was re-active to damage in the gyrus angularis region of the brain and that general intelligence, perceptual and reasoning abilities of children suffering from the disability are normal or above normal. A modified form of Hinshelwood's definition of word blindness is still used by some medical experts today. Since 1917, the United States of America and Scandinavian countries have been engaged in research into this topic and the last two years have seen an intensive renewal of interest in the United Kingdom.

Divergences of opinion have arisen between medical authorities and psychologists as to the causes and the nature of the phenomenon. Medical opinion attributes the causation to neurological deficit. Skydsgaard (1942) defines the condition as 'a primary constitutional reading disability which may occur selectively'. Critchley (1964) writes that the defect is of constitutional origin and often, if not always, genetically determined. He agrees with Hinshelwood's definition in that it is independent of the factor of intelligence, it is not due to peripheral visual anomalies but represents a higher level defect, an asymbolia. Difficulties, he says, lie in the 'flash' or global identifica-

tion of a word as whole and also in synthesising the word itself from its component letter units.

Some neurologists hold the view that the barrier in learning to read is the result of cerebral injury. Fisher (1910) describes dyslexia as being analogous to an acquired state of alexia (a condition seen in adults after a lesion or trauma involving one or both of the angular gyrii) and suggested that birth injury might predispose towards the condition. Kawi and Pasamanick (1959) also subscribe to the theory that some of the reading disorders in childhood may follow perinatal minimal cerebral injury. They postulate 'a continuum of reproductive casualty' extending all the way from death in utero and in the neonatal period to minimal cerebral damage component of this continuum. Reitan (1964) states that among the consequences of brain lesions are a loss in the ability to appreciate the significance of language symbols and deficits in the perception and manipulation of visuospatial configurations. Money (1962) points out the different functional effects of traumatic as compared with developmental dyslexia, in particular the greater plasticity of the immature brain and subsequent compensation for injury. The implication here would seem to be early diagnosis of infantile trauma to facilitate necessary therapeutic and remedial measures.

During the last three decades educational psychologists and sociologists have been investigating the problem of school learning failure in terms of psychogenic factors. Their standpoint is that educational difficulties in the main derive from various combinations of extrinsic conditions. In this country, Burt (1937) and Schonell (1948) described these precipitating factors together with diagnostic and remedial techniques. The problem of backwardness was related to the larger aspect of individual differences and a global view of personality development. Gates (1922) in America analysed the skills and perceptual abilities underlying the process of reading and developed tests of reading readiness. Malmquist (1958) has written a comprehensive account of investigations in Sweden into the factors involved in reading failure, especially from the practical educational standpoint. Vernon (1957) surveyed the whole field of reading difficulty, its nature and origin. Her list of the causal factors accepted by most educational psychologists include:

Inadequate readiness for reading.
Physical handicaps such as defective sight and hearing.
Neurological defects.
Internal secretionary disorders and low vitality.
General retardation of speech development and speech difficulties, special speech defects.
Limited vocabulary.
Restricted background of experience owing to social and cultural handicaps.
Personality factors, emotional difficulties and general adjustment difficulties.
Social factors.
Environment factors.
Irregular school attendance, frequent change of school or teacher.
Unfavourable home conditions.

Defective teaching methods and school organisation.
Inadequate supplies of reading material of satisfying interest value and too large classes.

A third and increasingly popular aspect of the dyslexia phenomenon lies in the area of cerebral dominance and it is this theme that runs centrally and consistently through the present investigation. The term 'cerebral dominance' owes its origin to the discovery that loss of speech (aphasia) almost always results from a lesion of the left hemisphere of the brain and especially the idea of Broca (1865) that both right-handedness and the lateralisation of speech are due to an innate functional pre-eminence of the left hemisphere.[1] Since then many investigators of language and handedness have postulated that cerebral dominance is less determinate in those who are left-handed or ambidextrous. Goodglass and Quadfasel (1954) suggest that cerebral ambilaterality is the rule in sinistrals, that speech is represented bilaterally, and that some aphasia is in consequence liable to accompany lesions of either hemisphere. Ettlinger, Jackson and Zangwill (1955) in a study of language failure allied to brain lesions conclude that although some degree of cerebral ambilaterality may exist in a certain proportion of cases, unilateral representation of speech (usually left but occasionally right) is the most prevalent form of cerebral organisation in sinistrals. Humphrey and Zangwill (1952) state that left-handedness does not imply strict dominance on the contralateral hemisphere, but shows all signs of less advanced specialisation. Humphrey (1951) makes the point that cerebral dominance either does not occur at all in the so-called left-handed, or if it does occur, tends to be less well developed than in the general run of right-handed persons. He also postulates that cerebral representation of the language functions in such cases is bilateral at least to a greater degree than in most right-handed people.

Why should the easy acquisition of language skills depend upon this type of neural association and integrity in the one hemisphere? Various hypotheses have been put forward in attempts to explain this causal relationship. Reading necessitates the ability to code meaningfully an ordered sequence of arbitrary symbols. Gerhardt (1959), writing of these interpretation difficulties in left-handed pilots, states: He (the pilot) would perceive a square, a house, a tree and the like with the same ease as others. Even though I have no difficulty in perceiving the forms in my environment, I may be confused or retarded when I get the task of seeing them in a special order, direction or sequence Mirror imaging and reversals are an ever-recurring feature of dyslexia. Orton (1937) and Wolfe (1941) comment on the difficulties shown by dyslexics in 'repicturing or rebuilding in the order of presentation, sequences of letters, of sound or of units of movement, a difficulty of acquiring series.' In Orton's view, it is the tendency to reversal which disturbs the acquisition of series and arises, according to him, from a failure to elide the mirror-image engrams in the non-dominant hemisphere. He describes the activity as 'looking at random'. Other writers ascribe the difficulties in the consistent ordering of symbols as due to the inability of the non-dominant hemisphere to suppress the mirror-image, making consistent pattern recognition impossible.

1 Research is at present being carried out in my department into the implications of cortical laterality for differential patterning of skills.

Bannatyne (1966) stresses the importance of the economy of neural connections in one dominant hemisphere in enabling meaningful sense to be made from written and spoken verbal material and the difficulties caused if language is subserved by both hemispheres. He quotes the visual/auditory 'four-way muddle', of b/d and p/q recognition.

In contrast to the difficulties experienced in coding arbitrary sequential symbolic material, as in verbal auditory abilities, evidence is accumulating to suggest that ambilaterality predisposes to good visuospatial ability. Claims have been made that there is a significant disparity between the scores of the Verbal and Performance sub-groups of the Wechsler Intelligence Scale in the case of dyslexic subjects. Rabinovitch (1954) cited a large discrepancy (averaging 22.1 points in favour of the performance tests) between verbal and performance intelligence quotients. Clinically the picture is often one of predisposition to artistic design and graphic ability in the ambilateral poor reader. Case histories reveal an association between a retarded developmental pattern of linguistic skills and subsequent success in civil engineering, architecture, dental surgery, draughtsmanship, tailoring, design and medicine. These histories also reveal genetic influences in the patterning of the various skills.

Extrinsic events also add to the laterality phenomenon. In 1961 Dr Marian Annett (1963) was studying the laterality implications of epileptic foci and her evidence supports this differential pattern of functioning. She has made an assumption which she is hoping to investigate further: that as spatial and orientation ability are a primary need of the organism for survival, a child damaged cortically will transfer spatial type association to the dominant hemisphere, to the detriment of language development.

Source of Hypothesis

Intensive work and research in the field of language learning failure amongst children of school age has been continuing in this country for over fifteen years. Treatment has emphasised therapeutic, remedial teaching methods aimed at resolving emotional and environmental causation of the reading failure. The evidence discussed in the above introduction, however, involving the possibilities of a neurological basis for certain types of difficulty in interpreting and expressing written text, has been accumulating from both educational and clinical sources.

In 1965 the following questionnaire was sent to several Birmingham primary schools. Teachers were asked to list the children who appeared to possess any of the symptoms.

Characteristic:

1. Clumsiness, e.g., difficulty in kicking, skipping, throwing, catching, climbing, etc.
2. Defective speech.
3. Lack of concentration.
4. Low tolerance of frustration at own achievements.
5. Difficulty with directional attack, i.e., reverses or confuses order of letters, words, phrases in reading and writing.
6. Seems 'odd'—different from other children.

7. Poor retention in learning to read new work.
8. Tendency to fall easily, accident proneness.
9. Left-handedness in writing or with tools.
10. Signs of ambi-dexterity.
11. Mirror writing.
12. Restlessness, hyperactivity.
13. Discrepancy between apparent 'brightness' and school progress.

Children presenting three or more of these characteristics were assessed for intelligence level and reading ability. The following points emerged:

All came within the normal or above normal range of intelligence and were seriously retarded in reading.

The positive responses represented about ten per cent of the school's population; in many cases, unresolved dominance together with faulty directional attack on letters and words were key features; in others, hyperkinesis and inability to sustain concentration were dominant.

The teachers, in the main, were unaware of the implications of neurological involvement: this meant that unsuitable methods of teaching had been practised, in many cases adding emotional factors to the primary difficulty.

The results of this pilot study supported the existing body of evidence and it seemed urgent that a scientific and well documented research programme should be mounted to establish the existence of this intractable type of learning difficulty so that awareness of the condition could be propagated and effective remedial treatment devised. The problem was to measure in some way and compare the activity of the two cerebral hemispheres.

Electroencephalography is the only method at present available by which measurement from the intact skull can be made of the activity of the brain (Walter 1953: Harding 1968 a and b). Consequently the hypothesis for the research became 'There is a difference in cortical lateral organisation between successful readers and children with the form of severe disability described as dyslexia, and that this difference can be manifested by using the techniques of electroencephalography'.

The research was carried out by the writer in 1966 in the Neuropsychology Unit attached to the Applied Psychology Department of Aston University, the EEG measurement being in collaboration with Dr Graham Harding.[2]

Material

Fifty children between the ages of eight and thirteen took part in the study. Twenty-five of these formed the experimental group, referred to as the 'cases', and twenty-five were the controls. The experimental group was composed of children referred to Child Guidance Clinics and the Child Study Centre of Birmingham University for severe reading difficulties and presented the aforementioned symptoms. The children were all within the normal intelligence range as measured by the Wechsler Intelligence Scale for Children and had normal school opportunities for acquiring experiences and skill in learning to read. They had also received from six to twenty-four (average fifteen) months' remedial tuition. This specialised teaching had been given

[2] Head of the Neuropsychology Unit in the Applied Psychology Department, Aston University.

by trained experienced teachers who had also attended post-graduate courses in remedial education. The average retardation of the group at the time of research testing was 4.1 years. The families' socio-economic status varied from professional level to unskilled manual workers. Details of prenatal history, birth trauma and genetic familial factors of the children were recorded.

This group was matched for intelligence, socio-economic level, school opportunities and age with a control group of normal readers drawn from a representative school in the suburbs of Birmingham. Although matched on these four variables the discrepancy in reading ability was between a mean of 10.3 years (controls) and a mean of 6.4 years (cases). (The school was selected after advice from the Senior Educational Psychologist,[3] Child Study Centre, University of Birmingham.)

Recording Procedure

The EEG recordings were made either in the school (controls) or in the Child Guidance Clinics (cases). The procedure was standardised for both groups. All readings were bi-polar, using silver stock-on electrodes placed according to the 10–20 international system. An Elther eight-channel portable electroencephalograph machine was used. A full routine record was taken for visual interpretation and in addition, tape recordings were made from right and left temporo-parieto-occipital derivations on a frequency modulated tape recorder. The tapes were subsequently replayed through the standard eight-channel Offner machine.

Analysis was carried out on the tape recorder derivations, using a four-channel low frequency BNL wave analyser. The filter trays in use for this study covered the frequencies 8, 9, 10, 11, 12 and 13 c/sec. The analyser was modified to provide a digital output of the abundance of each alpha frequency, which was automatically encoded and punched on to paper-tape for processing by an Elliot 803 computer. The statistical analyses carried out by the computer on the frequency analyses were as follows:

1. *Harmonic Mean*, a statistical procedure which is used to calculate the mean of data which are in rates, in this case cycles per second.
2. *Mean Abundance*, the arithmetic mean of the abundances of all frequencies.
3. *Kendall's Concordance*, a measure of the variability of the ranked analyser abundances from epoch to epoch. The score varies between zero and one, a score of one indicating no variability.

Results

Visual interpretation showed that of those showing evidence of unresolved dominance in the EEG recordings, 35 per cent were in the genetically determined group. A further 40 per cent of this unresolved dominance group were in the possible neurological-impairment determined group and 20 per cent of this latter group were in both genetic and neurological causation categories. These results support the writings of Critchley (1964) and also of

[3] Charles Phillips, Director, Child Study Centre, School of Education, University of Birmingham, to whom we are greatly indebted for his advice and co-operation in the planning of the research.

Kawi and Pasamanick (1959). In this small sample at least, ambilaterality is a critical feature of dyslexia and appears to be concomitant with both genetic and neurological symptoms.

Inter-group findings revealed significant differences in the amount of alpha activity in the two hemispheres between the experimental and control groups. Cases showed more activity on the dominant side or no difference at all, whereas the controls showed more activity on the non-dominant side—the alternation being on the dominant side where, according to Raney (quoted by Vernon, 1957) 'the central excitatory state and the peripheral nerve sensitivity is greater than those of the non-dominant side since the alpha rhythm is less', that is, cerebral activity is at its greatest. These findings could have implications, therefore, for facilitation or inhibition of learning in the areas of the cortex most commonly associated with the acquisition of language and especially of reading.

From the results of the automatic analysis of the EEG data, a more detailed comparison was made. In the cases of reading failure there appeared to be a smaller lateral difference occipitally in cortical organisation (Kendall's Concordance) but with a right sided predominance. Temporally there appeared firstly a smaller asymmetry of alpha and theta, indicating no defined cortical dominance, and secondly a lateral equivalence in cortical organisation (Kendall's Concordance). In the control group, however, the variability of cortical organisation as measured by Kendall's Concordance technique showed greater laterality differences. In the temporal regions there was asymmetry of the alpha rhythm indicating cortical dominance with an asymmetry of theta abundance also. (As the subjects were children, theta rhythm would be a normal developmental characteristic.) There was greater concordance in the right hemisphere. These findings again appear significant if we consider that the temporal regions are associated with the development of language skills, long term memory and auditory organisation, three critical prerequisites for the acquisition of reading skill.

The findings suggest a lateral dominance and cortical organisation present in the control group of normal readers. There is no comparable resolution of dominance in the cases group of dyslexics, a feature of both genetically and neurologically determined cases.

Conclusion

The high percentage of left-handed or ambidextrous subjects in the present study of reading failure supports the already vast accumulation of clinical evidence supporting this phenomenon as a critical feature of dyslexia. Roberts (1956) makes pertinent reference to this puzzling interdependence when he says, 'The development of handedness and the development of laterality for language are phenomena which are not in direct relationship or dependence, but the preference of the left hemisphere for both indicates that some common factor favouring the left hemisphere must be responsible'. Another interesting related phenomenon is the high spatial ability often associated with subjects who are handicapped in a verbal society by low linguistic coding skills. Does an equivalence of hemispheric functioning predispose to superior processing of spatial-type information? Finally, what support do the EEG findings in the present study give to the above hypo-

theses and opinions? Graham Harding writes elsewhere, 'The EEG is a reflection of bio-physical and chemical disturbances in neurones. The electrical changes are concomitants of these actions and have the advantage that, with modern electronic techniques, they are more easily recordable from the intact subject than the primary activities. A study of spontaneous activity of the brain assumes that changes of frequency and amplitude . . . are meaningful reflections of internal events.' The equivalence of electrical activity in the temporo-occipital areas from both hemispheres recorded by the experimental group of children (the non-readers) *vis-à-vis* the differences in activity of the same areas in the control group (good readers), with the more excitatory activity predominant in the left hemisphere, does appear to suggest neurological confirmation of the necessity for resolution of cortical, hemispheric dominance to facilitate the acquisition of language skills. Is this resolution of dominance a specific developmental condition of cortical association areas making possible an ordered, sequential arbitrary coding of symbolic material? Is it possible also that the so-called secondary dyslexia is the specific type of stress manifestation under environmental pressures, because of this type of predisposition?

Bearing in mind the particular association areas involved and their critical role in the nature of the task under discussion, we can end by quoting once more from the paper by Gerhard (1959), 'If we could isolate different functions in our laterality research, we could reach a conclusion about this problem. For instance, one could claim that different cortical areas might as well have a laterality fixed independently of the other ones. As a consequence we might come to see a laterality pattern, variations in which would be one of the reasons for individual differences in behaviouristic and perceptory tendences. It would also be pertinent to the problem of individual differences in learning certain activities.'